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WITH A BALANCED SPLIT FLAP

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L - 264

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SUMMARY

A pressure-distribution investigation has been conducted in the NACA 4- by 6-foot vertical wind tunnel to determine the air loads on an airfoil with a 22.1-percent-chord balanced split flap. Pressures were measured on both the upper and the lower surfaces of the airfoil and the flap for several angles of attack and for several flap deflections.

The data, presented as pressure diagrams and as graphs of the section coefficients for the airfoil-flap combination and for the flap alone, are applicable to the structural design of an airfoil with a balanced split flap. The results of previous tests of an airfoil with an external-airfoil flap, a Fowler flap, and slotted flaps of similar dimensions have been compared with the present results.

It is believed that the results are applicable to airfoils of different thickness and to symmetrical or moderately cambered airfoils of similar contour. The results show that the normal-force coefficients for the various balanced split-flap settings are generally similar to the values for the external-airfoil flap, the Fowler flap, or the slotted flap.

INTRODUCTION

The National Advisory Committee for Aeronautics has been conducting an extensive investigation of air loads on promising airfoil-flap combinations. One of the combinations is an airfoil with a balanced split flap. Aerodynamic data for a balanced split flap on an airfoil have been made available in references 1 and 2. Data for the structural design of an external-airfoil flap, a Fowler flap, a plain

flap, and several slotted and split flaps on airfoils of various thickness are presented in references 3 to 8. No data, however, have been published for the structural design of a balanced split flap. The present report was prepared to make available load data obtained in a special investigation by the NACA of an airfoil with a balanced split flap.

The pressure-distribution data were obtained from tests, in the 4- by 6-foot vertical wind tunnel, of a 14.1-percent-thick airfoil with a balanced split flap having a chord of 22.1 percent of the airfoil chord. The tests were made at various angles of attack and flap deflections.

APPARATUS AND TESTS

Model

The 3-foot chord by 4-foot span model of the airfoil-flap combination was built of laminated mahogany and conformed to the airfoil profile given in table I (fig. 1). The basic airfoil has a symmetrical profile behind the 15-percent station and has some camber ahead of this station. The maximum ordinate is 14.1 percent of the airfoil chord. The airfoil profile is an intermediate section obtained from a wing having a symmetrical root section and a cambered tip section. The airfoil model has a hollow section to accommodate the copper pressure tubes.

The full-span balanced split flap has a chord of 7.95 inches (22.1 percent of airfoil chord) and conforms to a modified NACA 2309 airfoil section (fig. 1, table I). The flap is attached to the airfoil with metal fittings at each end that allow for flap deflections and positions shown in figure 1.

The airfoil and the flap are fitted with a single row of pressure orifices along the midspan section, distributed chordwise as shown in table II and figure 1. The pressure tubes are brought out one end of the model and connected to a multiple-tube manometer that records photographically.

Test Installation

The model was mounted in the closed test section of

the NACA 4- by 6-foot vertical wind tunnel (references 8 and 9). Because the model completely spanned the tunnel except for small clearances at each end, the sides of the tunnel acted as end plates and approximately two-dimensional flow was obtained. Torque tubes attached to the balance frame held the model rigidly and also served as a conduit for the pressure tubes. The angle of attack was set from outside the tunnel by rotating the torque tubes with a calibrated electric drive.

Tests

The tests were run at an average dynamic pressure of 10.8 pounds per square foot, which corresponds to an air speed of about 65 miles per hour at standard sea-level conditions. The effective Reynolds number was about 3,410,000 and is equal to the test Reynolds number multiplied by 1.93, the turbulence factor for the 4- by 6-foot vertical tunnel.

The model was tested at eight flap deflections from fully retracted to 45°; the deflections and the locations are shown in figure 1. These tests were made through an angle-of-attack range from -15° to 20° in 5° increments. When the model was at a given angle of attack and flap setting, time was allowed for conditions in the tunnel and for the manometer to become stable before the pressures were recorded.

PRESENTATION OF DATA

Pressure Curves

All the diagrams of pressure over the upper and the lower surfaces of the airfoil combination are plotted as pressure coefficients P where

$$P = \frac{p - p_0}{q}$$

and

p static pressure at a point on airfoil

p_0 static pressure in free air stream

q dynamic pressure of free air stream

Isometric diagrams of the pressures over the airfoil and the flap are given in figures 2 to 9. In these figures the pressures over the airfoil are plotted normal to the airfoil chord and the pressures over the flap are also plotted normal to the airfoil chord but along the projected flap chord for the flap fully retracted.

Coefficients

The pressure diagrams were mechanically integrated to obtain data from which standard section coefficients were computed. Where the term "flap alone" is used, it refers to the forces on the flap in the presence of the main portion of the airfoil. The section coefficients are defined as follows:

c_n normal-force coefficient of airfoil with flap $\left(\frac{n}{qc}\right)$

c_{n_f} normal-force coefficient of flap alone $\left(\frac{n_f}{qc_f}\right)$

c_m pitching-moment coefficient of airfoil with flap about quarter-chord point of airfoil with flap fully retracted $\left(\frac{m}{qc^2}\right)$

c_{m_f} pitching-moment coefficient of balanced flap alone about quarter-chord point of flap $\left(\frac{m_f}{qc_f^2}\right)$

c.p. center-of-pressure location of airfoil with flap in percent airfoil chord from leading edge of airfoil $\left[\left(0.25 - \frac{c_m}{c_n}\right) 100\right]$

where

n normal force on airfoil with flap

n_f normal force on flap alone normal to chord of flap

m pitching moment of airfoil with flap, about quarter-chord point of airfoil

m_f pitching moment of flap alone, about quarter-chord point of flap

q dynamic pressure of free air stream $(\frac{1}{2} \rho V^2)$

c chord of airfoil with flap fully retracted

c_f chord of flap, over-all length of flap

and

α_o angle of attack for infinite aspect ratio

δ_f angle of flap deflection, angle between flap chord line and airfoil chord line

The coefficients for the combination were derived from the normal forces alone, the chord forces of the flap being neglected. Inasmuch as the model completely spanned the test section, the integrated results, which are in coefficient form, may be used as section characteristics.

Figures 10 and 11 show the section characteristics of the airfoil-flap combination and of the flap alone, respectively.

Precision

No air-flow alinement tests were made in the tunnel with the test arrangement used in the present investigation. The absolute angle of attack may, therefore, be in error, but the relative angles of attack of the model are accurate to within $\pm 0.1^\circ$. The flap was set at specified angles to within $\pm 0.5^\circ$. It is believed that the individual point pressures are accurate to within about ± 2 percent except at high angles of attack where the error might be as much as ± 5 percent near the airfoil nose. The individual free-stream dynamic pressures are accurate to within ± 1 percent. The tunnel-restriction correction explained in reference 10 has been applied only to the normal-force coefficient of the combination. This correction, which tends to reduce the magnitude of the pressures, has not been applied to the point pressures. The results should, therefore, be conservative.

DISCUSSION

Section Pressure Distribution

The pressure curves (figs. 2 to 9) show the distribution of load over the upper and the lower surfaces of the airfoil-flap combination for several flap deflections. These curves may be used in the design of ribs of airfoils with flaps and may also be used to show the change in distribution of load over the airfoil as the flap is deflected. The pressures over the upper and the lower surfaces of the airfoil with a balanced split flap differ from the pressures over an NACA 23012 airfoil in combination with a Fowler or an external-airfoil flap (references 3 and 4) in the following manner: The peak nose pressures are higher on the airfoil with balanced split flap in the high angle-of-attack range. The pressures over the lower surface of the airfoil back of the flap nose increase negatively and thus decrease the load carried on that portion of the airfoil.

The negative increase of the lower-surface pressures on the airfoil behind the flap nose explains to some extent the decrease in lift coefficient when the flap is moved from the trailing edge of the airfoil to the position investigated.

The pressures over the upper and the lower surfaces of the balanced split flap are similar to the pressures over an external-airfoil or a Fowler flap on an NACA 23012 airfoil (references 3 and 4). In the range of flap deflections where the flap is not stalled, a large increase in peak pressure over the nose of the flap was observed when the main portion of the airfoil stalled. At a flap deflection of 45° the balanced split flap was completely stalled for all angles of attack.

Aerodynamic Section Coefficients

The section characteristics of the combination are shown in figure 10. The value of the maximum normal-force coefficient for a given flap deflection is less than the values reported in reference 1 for a flap in the same position. This decrease in normal-force coefficient is probably caused by the difference in maximum normal-force coefficients of the plain airfoils. Because the increments

of angle of attack are large, no accurate comparison of maximum normal-force coefficients is possible.

A comparison of the section characteristics of the flap alone (fig. 11) and of the combination (fig. 10) shows that the loads on the flap built up more slowly than did the loads on the combination. The values for c_{n_f} for the balanced split flap at several small flap deflections were about the same as for the external-airfoil flap, the Fowler flap, and the slotted flap; but at large flap deflections the values of c_{n_f} were less than the values for the other flaps. This result was expected because of the interaction between the lower surface of the airfoil and the upper surface of the flap, which tended to decrease the load on the flap. In the range of flap deflection in which the flap is not stalled, the values of c_{n_f} are comparable with those of the external airfoil, the Fowler flap, and the slotted flaps. The extension of the trailing edge of the airfoil back of the flap nose apparently decreases the effectiveness of the flap on the air flow about the airfoil, thus causing a decrease in normal-force coefficient for the arrangement.

The pitching moments for the balanced split flap at small flap deflections were generally less than for the Fowler, the slotted, or the external-airfoil flap, but the balanced split flap gave the highest flap pitching moments at large flap deflections when the flap was stalled.

CONCLUDING REMARKS

It is believed that the results of this investigation are applicable to airfoils of different thickness and of similar contour. Previously published data for the slotted flap on two airfoils of different thickness and for the Fowler flap on two airfoils of the same thickness and different but similar contours showed very little change in pressure distribution with airfoil thickness or with a slight change in airfoil contour.

It should be noted, however, that the flap locations given in this investigation are not the optimum, but a slight change in the flap location should have only a slight effect on the pressure distribution.

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L-264

TABLE I

AIRFOIL AND FLAP ORDINATES

(All stations and ordinates in percent wing chord)

Airfoil section		
Station	Upper surface	Lower surface
0	---	---
1.25	1.98	-2.48
2.5	2.87	-3.29
5	3.99	-4.31
7.5	4.84	-5.02
10	5.45	-5.54
15	6.26	-6.28
20	6.72	-6.72
25	6.97	-6.97
30	7.03	-7.03
40	6.80	-6.80
50	6.21	-6.21
60	5.34	-5.34
70	4.30	-4.30
80	3.07	-3.07
90	1.70	-1.70
95	.94	-.94
100	.03	-.03

L.E. radius: 2.23.
L.E. radius is 0.35 below chord line and slope is 0.071. (See fig. 1.)

Flap section		
Station	Upper surface	Lower surface
0	0	---
.55	.35	-0.66
1.10	.63	-.65
2.21	1.02	-.63
3.31	1.21	-.62
4.42	1.35	-.60
5.52	1.41	-.58
6.62	1.44	-.55
8.83	1.40	-.53
11.04	1.29	-.47
13.25	1.12	-.42
15.46	.91	-.30
17.66	.65	-.21
19.87	.36	-.12
20.98	.19	-.07
22.08	---	---

L.E. radius: 0.38.
L.E. radius is 0.29 below chord line.

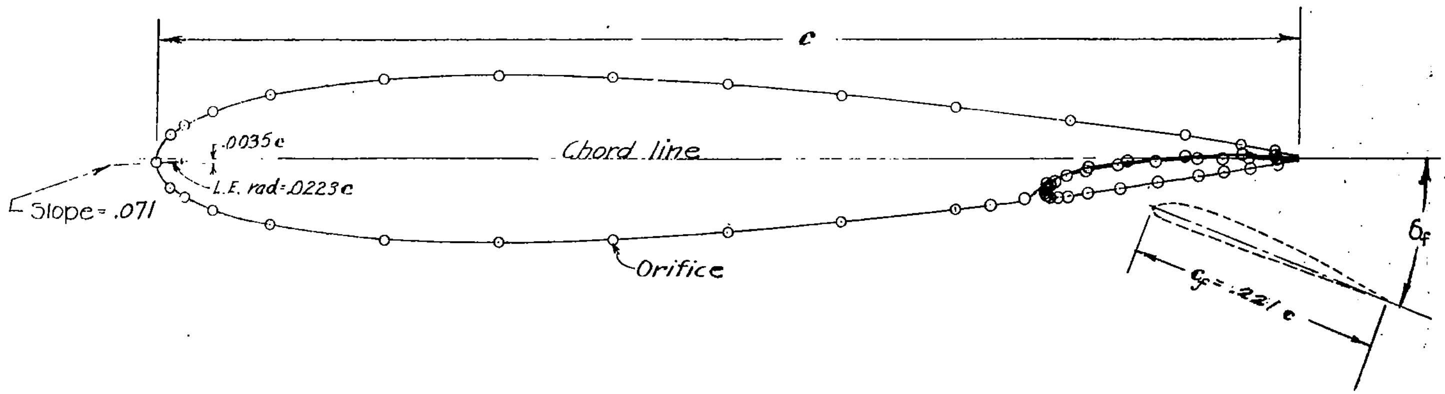
TABLE II

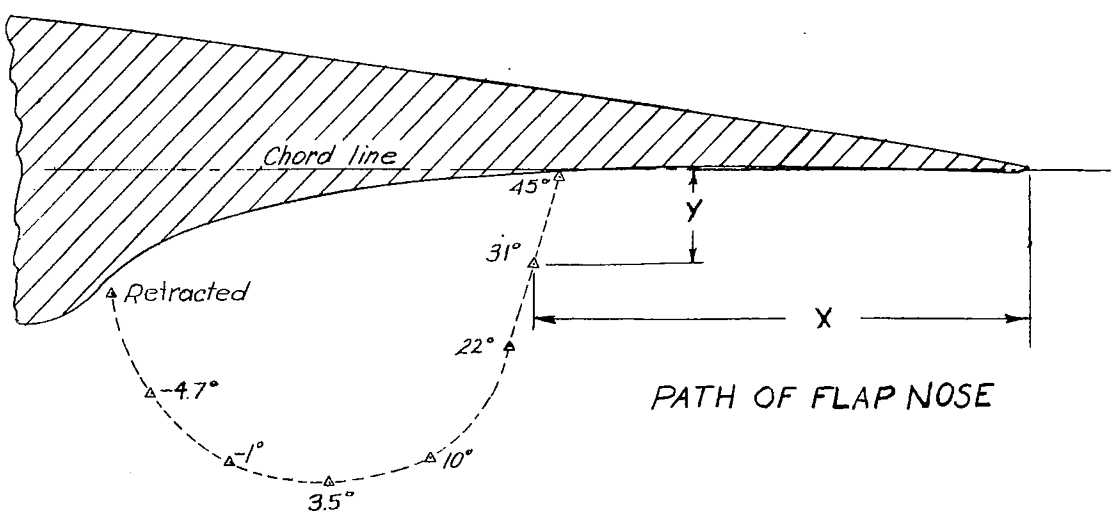
ORIFICE LOCATIONS ON THE AIRFOIL AND BALANCED FLAP

Wing		Flap	
Orifice	Location (percent c)	Orifice	Location (percent c_f)
0	0	0	0
1	1.25	1	1.25
2	2.50	2	2.50
3	5.00	3	5.00
4	10.00	4	10.00
5	20.00	5	18.00
6	30.00	6	30.00
7	40.00	7	45.00
8	50.00	8	62.50
9	60.00	9	72.50
10	70.00	10	82.50
11	[a]73.00	11	92.50
12	[a]76.00		
13	[a]78.00		
14	[b]80.00		
15	[a]81.50		
16	[a]85.00		
17	90.00		
18	95.00		
19	98.00		

[a]Lower surface only.

[b]Upper surface only.





δ_f (deg)	Y (percent c)	X (percent c)
Retracted	2.8	22.2
-4.7	5.2	21.2
-1	6.8	19.1
3.5	7.2	16.8
10	6.3	14.4
22	4.1	12.5
31	2.0	11.9
45	.1	11.4

FIGURE 1.- Cross section of model showing airfoil-flap combination.

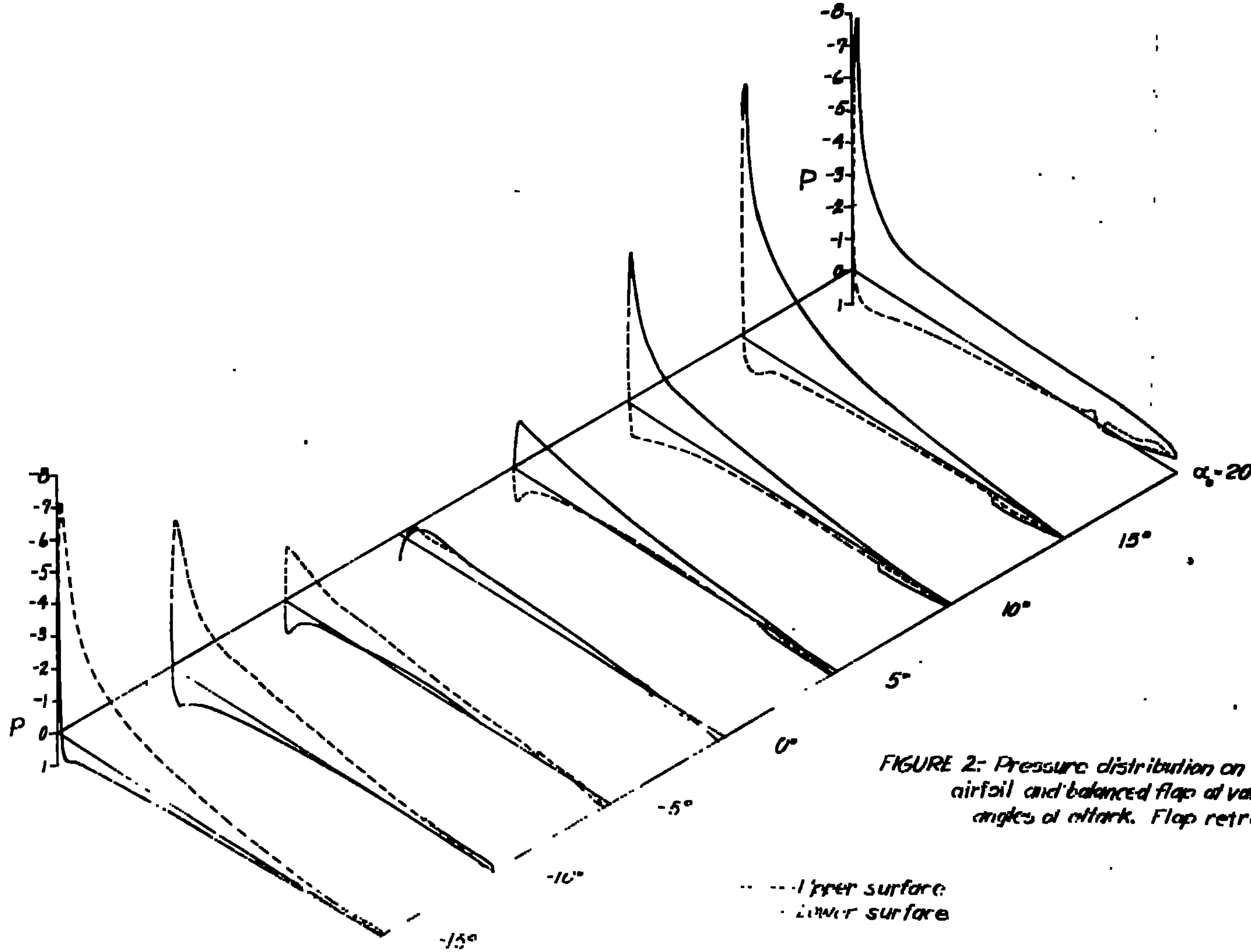


FIGURE 2.- Pressure distribution on the airfoil and balanced flap at various angles of attack. Flap retracted.

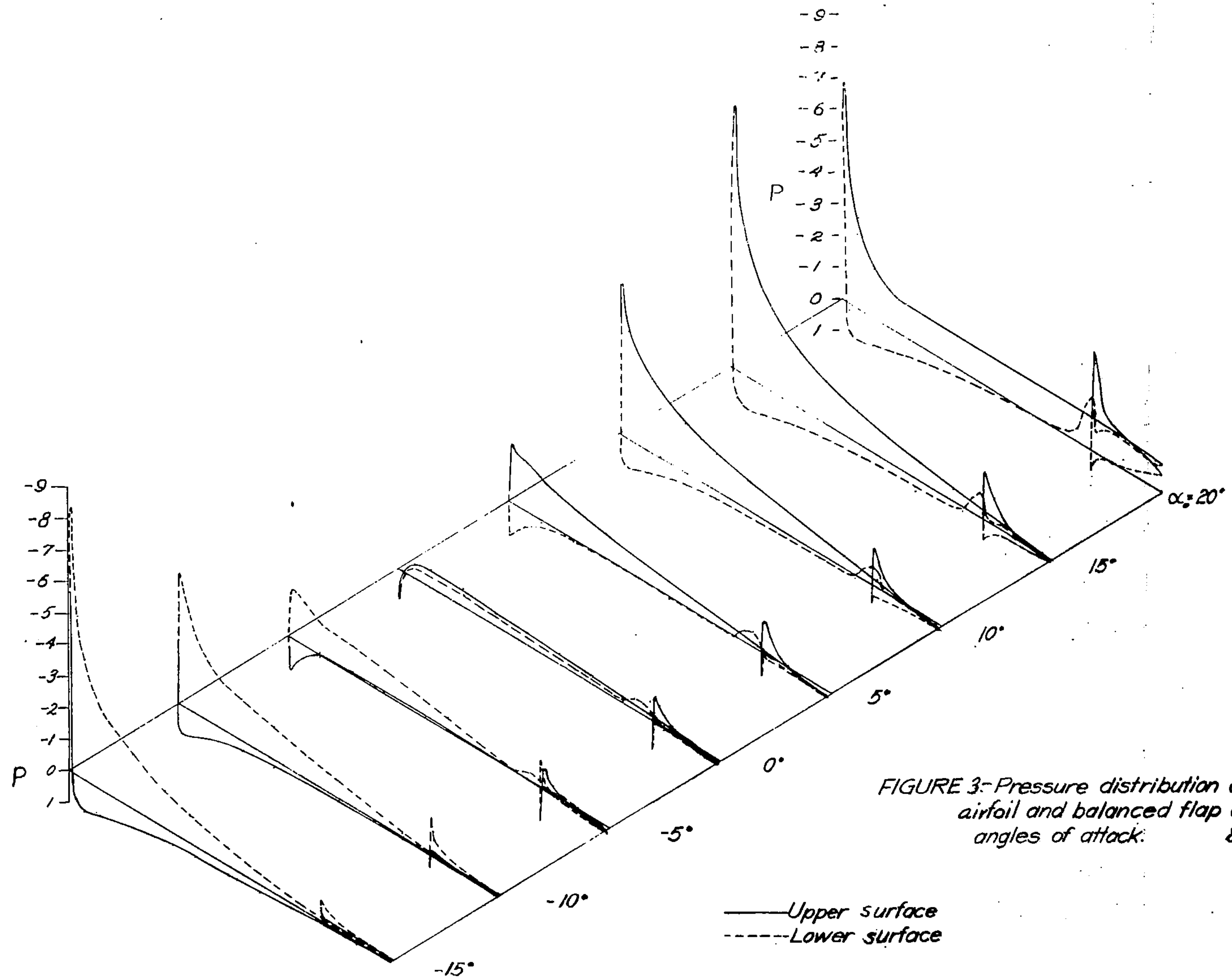


FIGURE 3.- Pressure distribution on the airfoil and balanced flap at various angles of attack. $\delta_f = -4.7°$

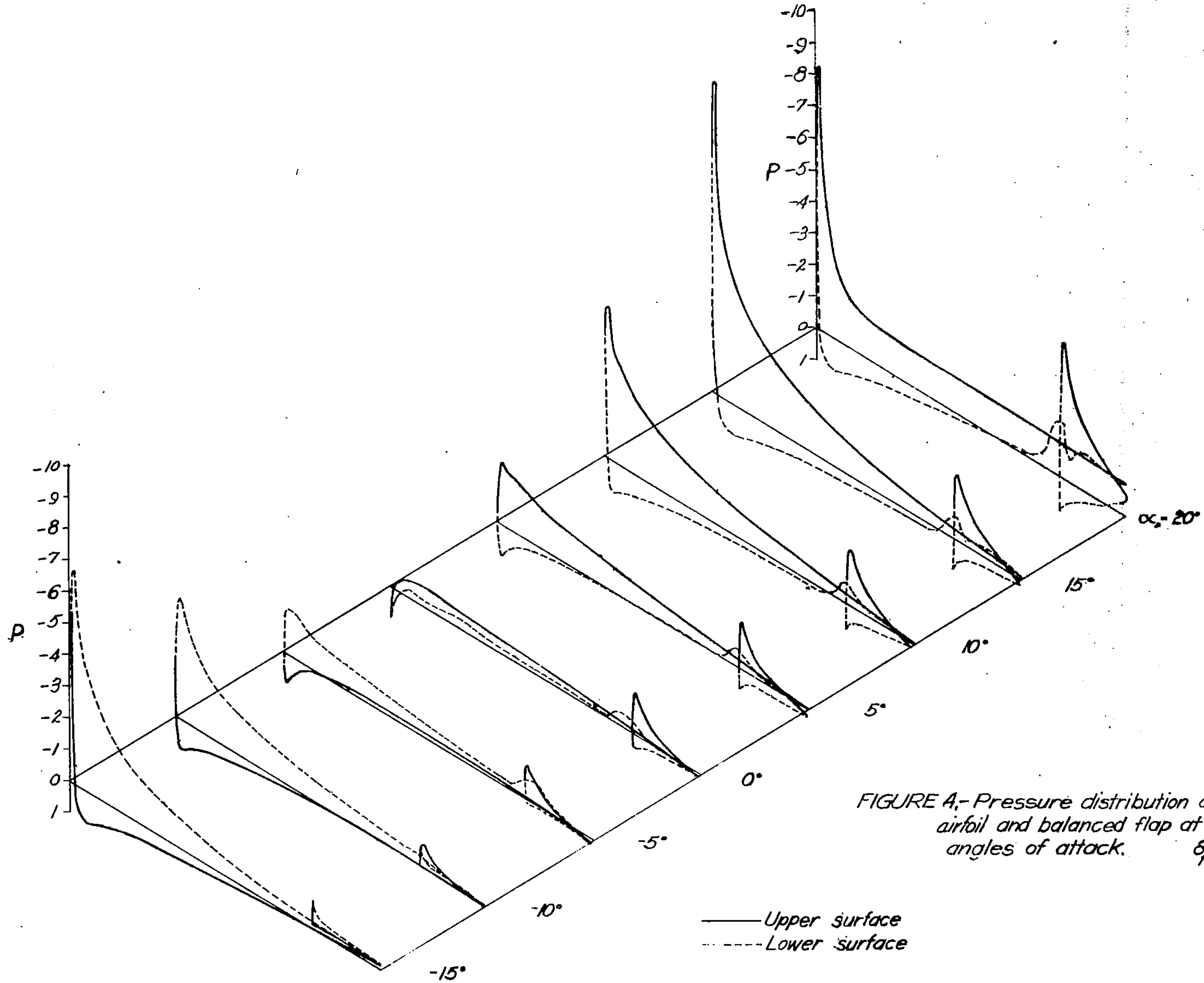


FIGURE 4.- Pressure distribution on the airfoil and balanced flap at various angles of attack. $\delta_f = -1°$.

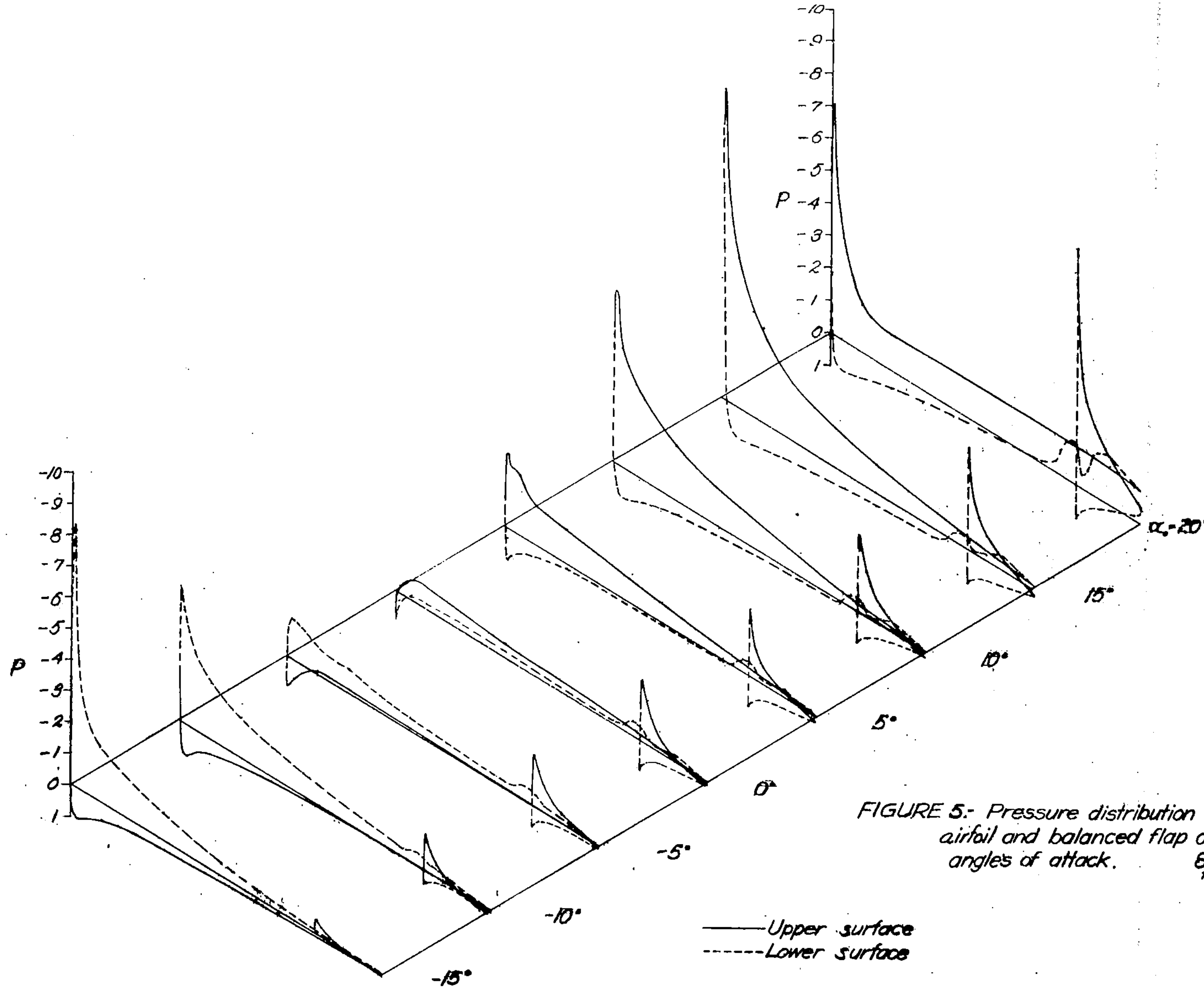


FIGURE 5.- Pressure distribution on the airfoil and balanced flap at various angles of attack. δ_f = 3.5°.

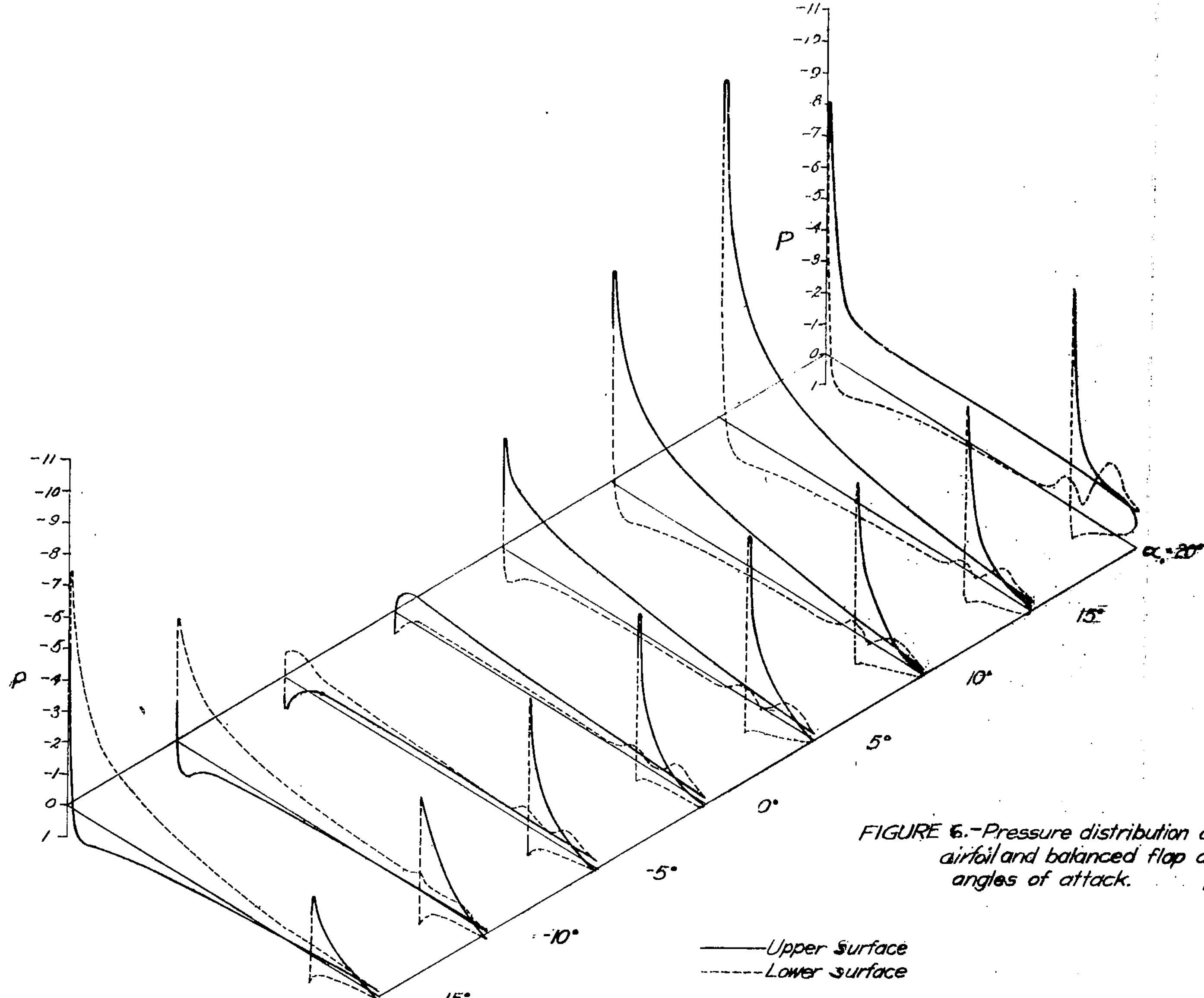


FIGURE 6.-Pressure distribution on the airfoil and balanced flap at various angles of attack. $\delta_f = 10°$.

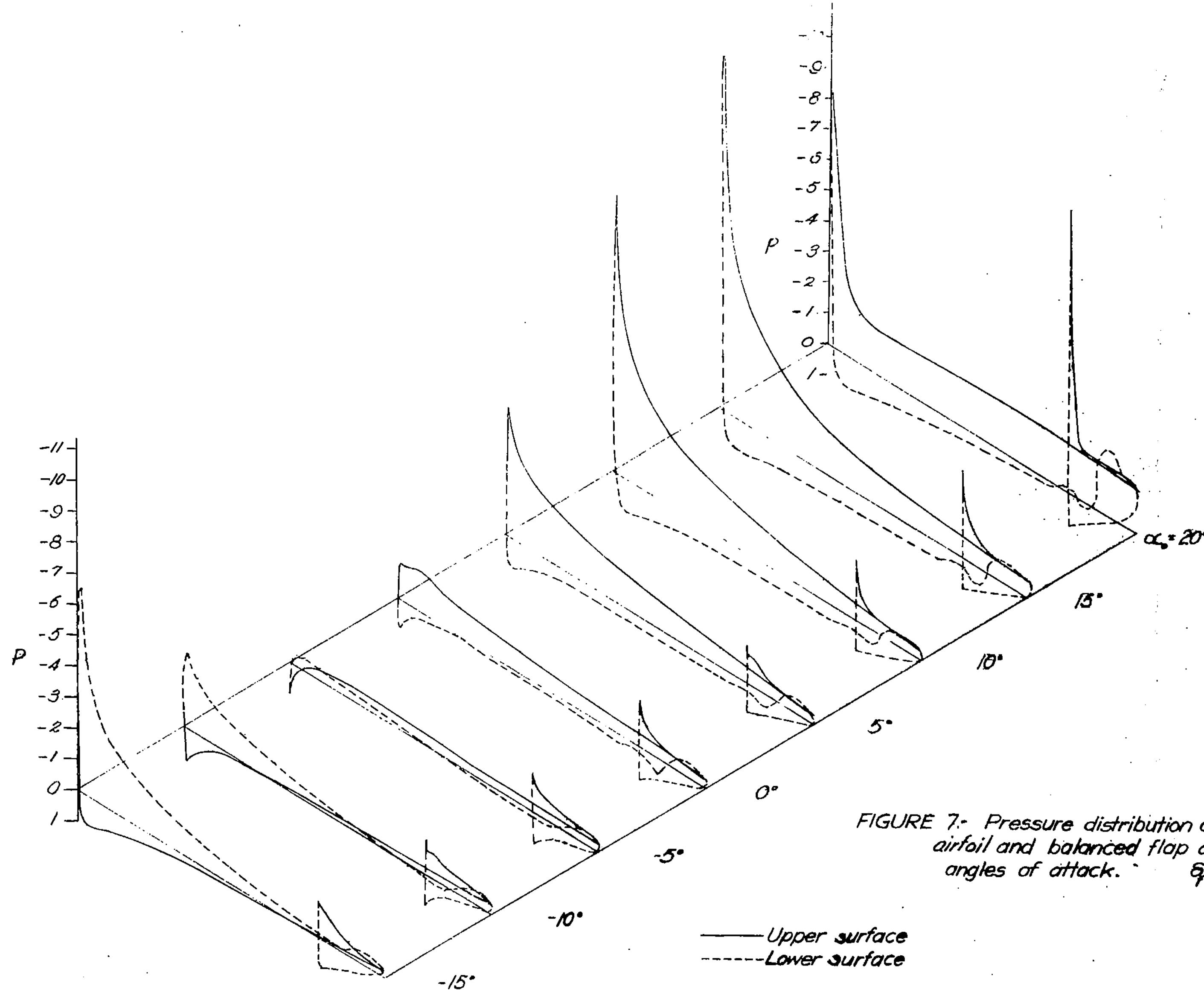


FIGURE 7.- Pressure distribution on the airfoil and balanced flap at various angles of attack. δ_f = 22°.

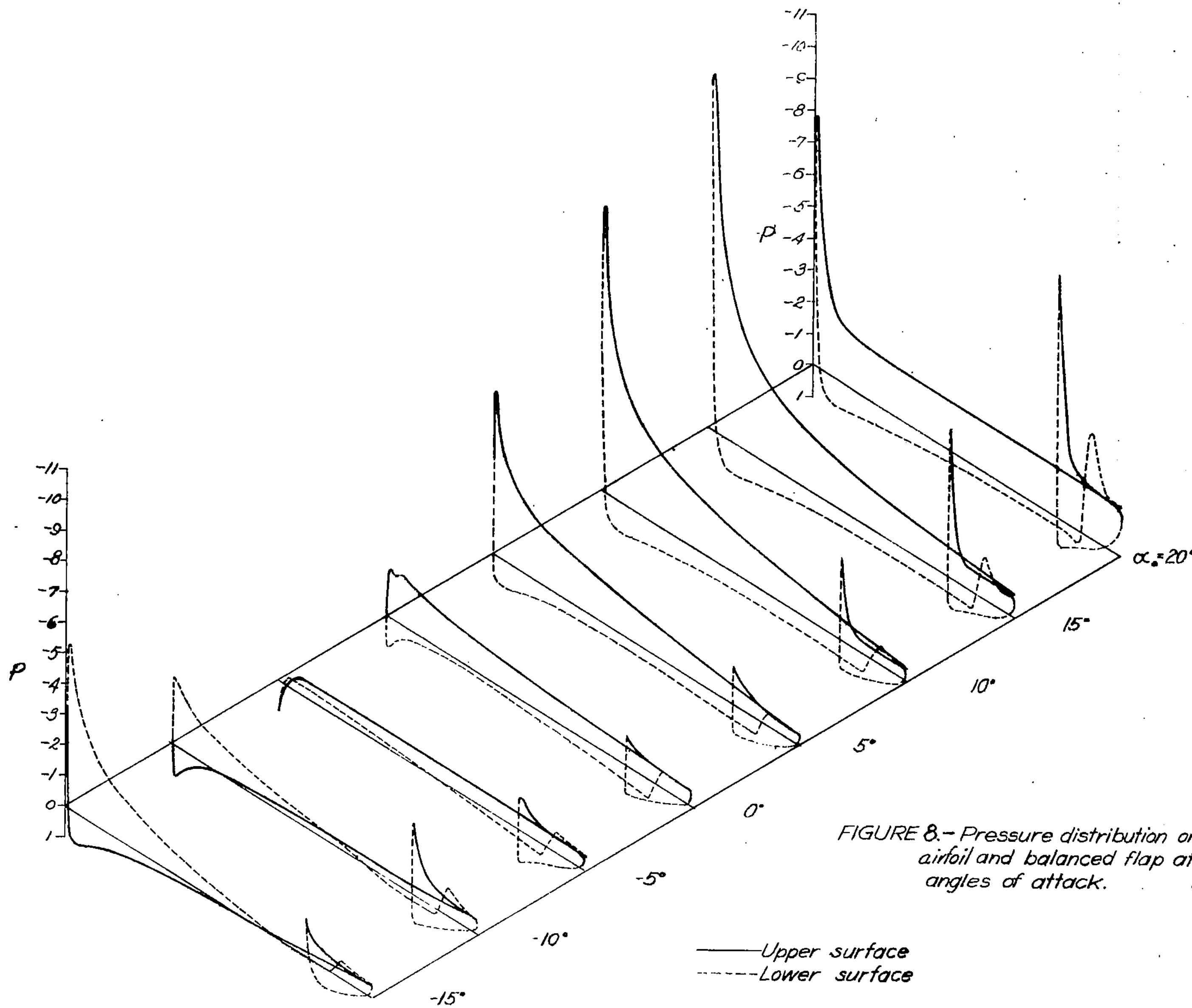


FIGURE 8.– Pressure distribution on the airfoil and balanced flap at various angles of attack. $\delta_f = 31°$.

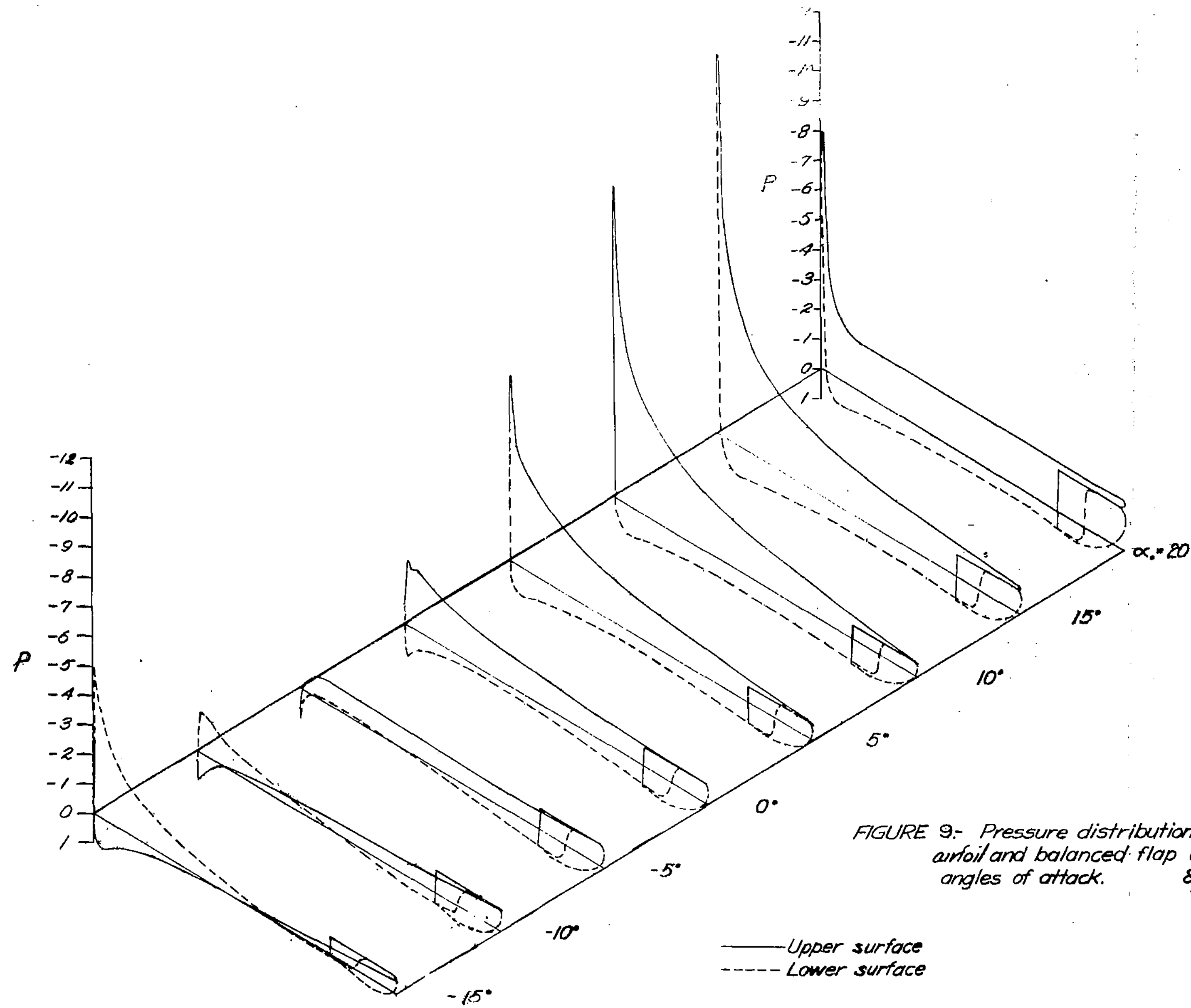


FIGURE 9.- Pressure distribution on the airfoil and balanced flap at various angles of attack. $\delta_f = 45°$

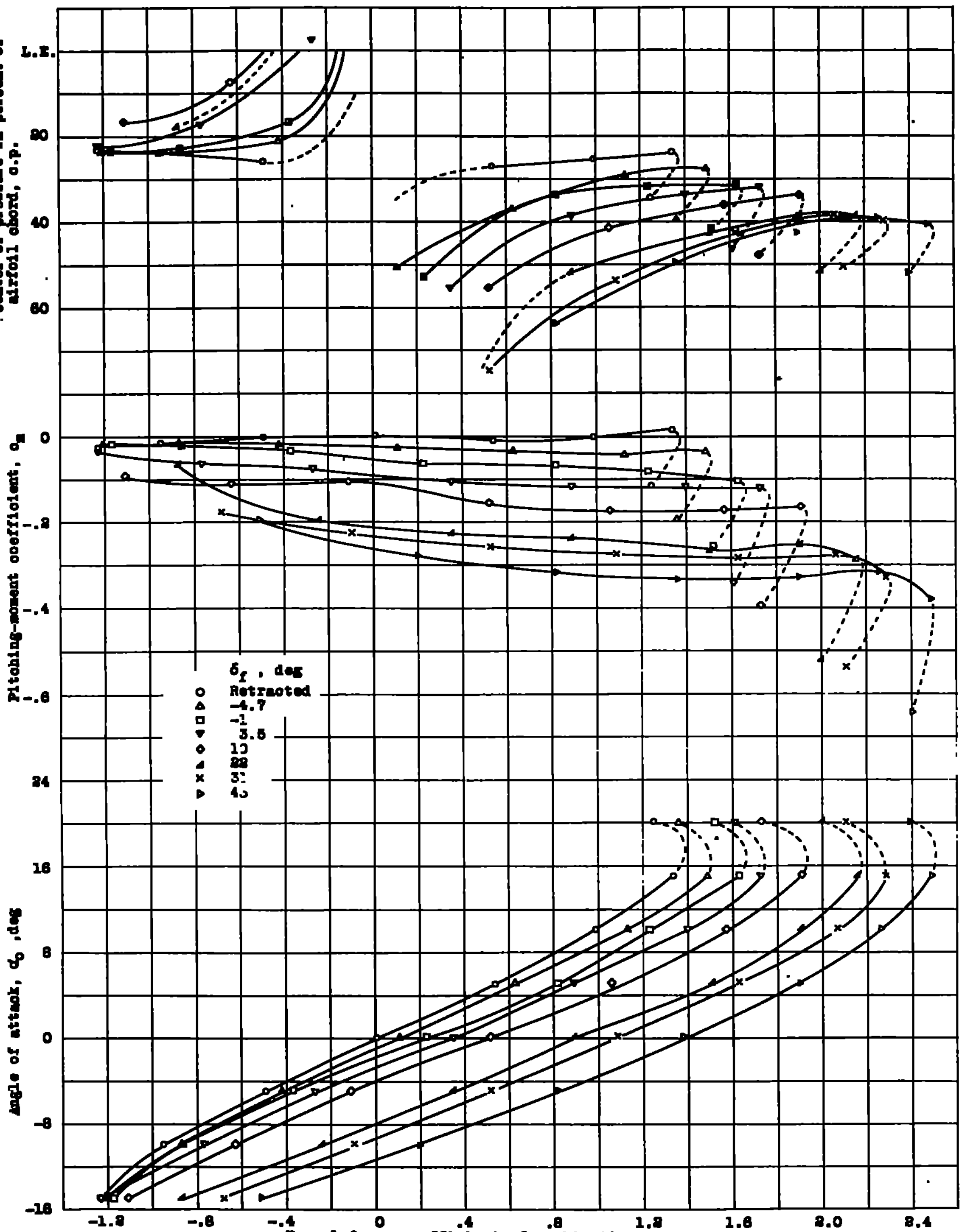


Figure 10.- Section characteristics of the airfoil with the 0.221c balanced split flap.

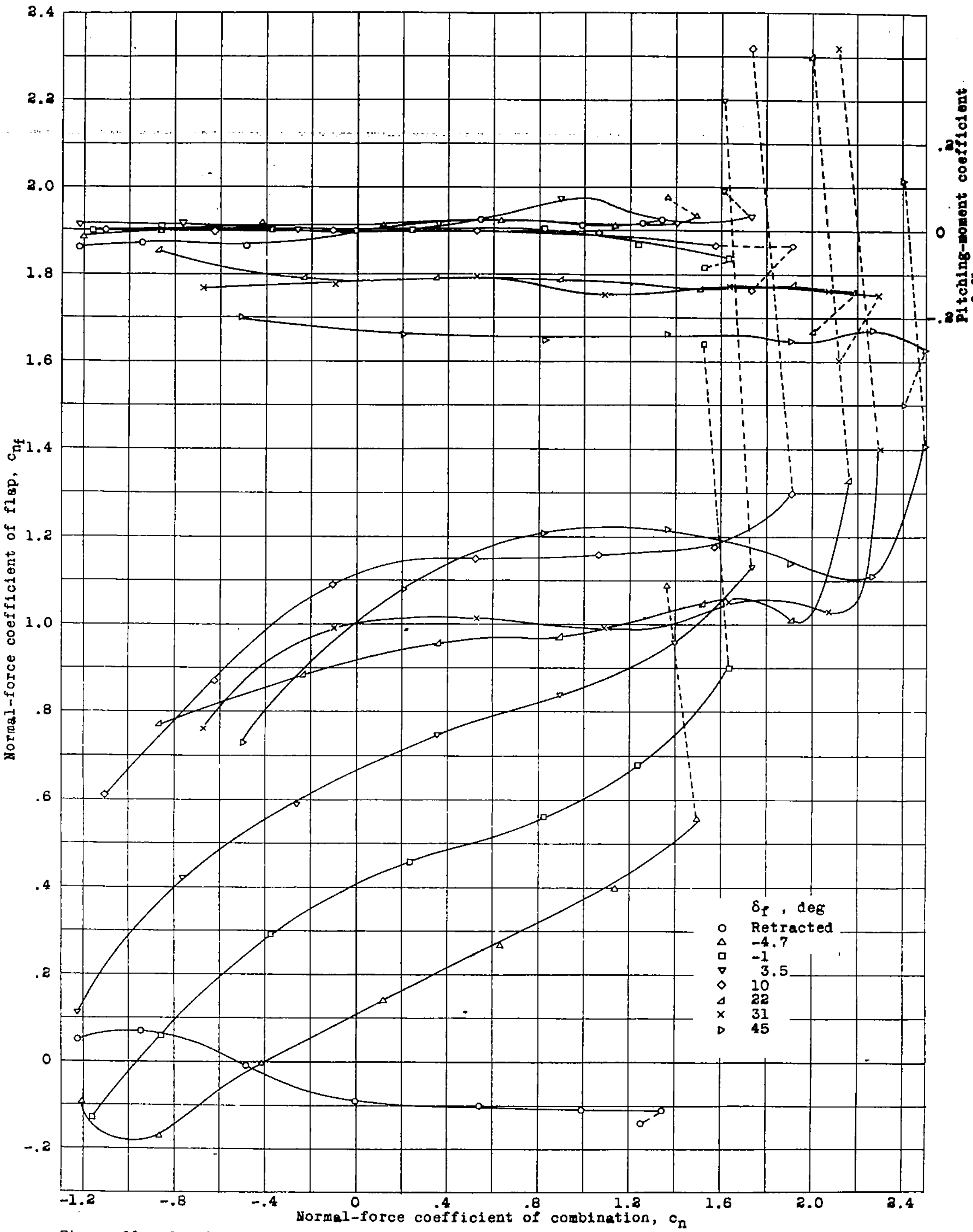


Figure 11.- Section characteristics of the balanced flap.